Diffuser Calibration Facility

Goddard Space Flight Center

NASA

BSDF Measurement Uncertainty

In accordance with the NIST guidelines for evaluating and expressing the uncertainty of measurement results [1], the uncertainty of BSDF measurements from the NASA DCaF scatterometer can be calculated. The uncertainty in BSDF measurements from the scatterometer has been presented previously [2] and will be briefly summarized here.

The uncertainty or error in a BSDF measurement, Δ_{BSDF}, is presented in equation 1.

$$(\Delta_{BSDF})^2 = 2(\Delta_{NS})^2 + 2(\Delta_{LIN})^2 + (\Delta_{SLD})^2 + (\Delta_{\theta s}\tan(\theta_s))^2 \quad (1)$$

In equation 1, Δ_{NS} is the signal to noise ratio, Δ_{LIN} is the non-linearity of the detector and electronics, Δ_{SLD} is the uncertainty in the determination of the receiver solid angle, $\Delta_{\theta s}$ is the uncertainty in the total scatter angle, and θ_s is the scatter elevation angle of the detector. The uncertainty in the receiver solid angle, Δ_{SLD} , can be further broken down into the uncertainty components shown in equation 2.

$$(\Delta_{SLD})^2 = (2\Delta_{RM})^2 + (2\Delta_{RZ})^2 + (2\Delta_{RA})^2 \quad (2)$$

In equation 2, Δ_{RM} is the uncertainty in the receiver arm radius, Δ_{RZ} is the uncertainty in the arm radius due to misalignment of the sample in the z direction, and Δ_{RA} is the uncertainty in the receiver aperture radius. In equation 1, the total scatter angle uncertainty, $\Delta_{\theta s}$, can be further broken down into the uncertainty components shown in equation 3.

$$(\Delta_{\theta s})^2 = (\Delta_{\theta M})^2 + (\Delta_{\theta Z})^2 + (\Delta_{\theta T})^2 \quad (3)$$

In equation 3, $\Delta_{\theta M}$ is the scatter angle uncertainty due to the receiver arm, $\Delta_{\theta Z}$ is the scatter angle uncertainty due to sample misalignment in the z direction, and $\Delta_{\theta T}$ is the scatter angle uncertainty due to error in the sample tilt.

Table 1 presents values for the uncertainty components presented in equations 1 through 3. The method of determination of values for these components is also indicated. Quadrature sum squaring of all the uncertainty elements produces the overall measurement uncertainties shown at the end of Table 1.

Table 1. Uncertainty Analysis of BSDF Measurements from NASA's GSFC DCaF Scatterometer

Uncertainty Component	**Uncertainty**	**Method of Determination**
Δ_{NS}	0.001 at 230nm	Measurement
Δ_{LIN}	0.0035	Measurement using ND filters
Δ_{SLD}		
Δ_{RM}	0.2mm	Measurement using dual theodolites
Δ_{RZ}	0.2mm at 15 degrees 0.15mm at 45 degrees 0.05mm at 75 degrees	Measurement using dual theodolites
Δ_{RA}	0.01mm	Measurement through THR integration
$\Delta_{\theta s}$		
$\Delta_{\theta M}$	0.035 degrees	Measurement using dual theodolites
$\Delta_{\theta Z}$	0.007 degrees at 15 degrees 0.019 degrees at 45 degrees 0.025 degrees at 75 degrees	Measurement using dual theodolites
$\Delta_{\theta T}$	0.05 degrees	Conservative estimate based on actual sample alignments
Overall Uncertainty	0.61% at 15 degrees 0.61% at 45 degrees 0.74% at 75 degrees	QSS of uncertainty components

References

[1] Barry N. Taylor and Chris E. Kuyatt, "A Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results", NIST Technical Note 1297, U.S. Department of Commerce, National Institute of Standards and Technology, September 1997.

[2] Tod F. Schiff, Mary W. Knighton, Daniel J. Wilson, Fred M. Cady, John C. Stover, and James J. Butler, "A Design Review of a High Accuracy UV to Near Infrared Scatterometer", Proceedings of the International Society for Optical Engineering, 1995, 121-130 (1993).